LAND ALLOCATION IN THE SOUTHEASTERN U.S. IN RESPONSE TO CLIMATE CHANGE IMPACTS ON FORESTRY AND AGRICULTURE

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ABSTRACT

Forest and agriculture are the two dominant land uses in the Southeastern U.S., collectively accounting for almost 90 percent of the land base. Differences in climate change impacts on forest and agricultural productivity can lead to reallocations of land between the two sectors as landowners adjust to the changes in economic conditions. In this paper, we apply the impacts of climate-induced changes in forest and agricultural economic rents to a model of land allocation for the Southeastern U.S. Climate change impacts on land use are evaluated relative to the demographic and commodity market factors that will affect future land uses independent of climate change.

1 INTRODUCTION

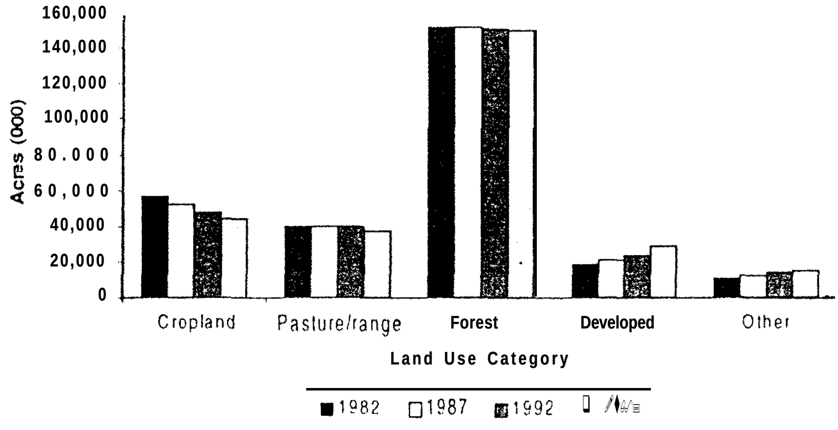
Forests and agriculture are the predominate uses of land in the Southeastern U.S. Because much of the region's topography is well-suited to both uses, the momentous changes in economic forces that affect land use have caused a substantial amount of land to move between forest and agriculture over the last century (Healy, 1985). In the Southeast, land is almost exclusively owned by private parties and its use is thereby influenced by market forces that determine the economic returns to alternative land uses. In this assessment, we see how climate change may affect the economic returns to agriculture (Hatch et al., 2000) and forests (Abt et al., 2001) and thereby alter the allocation of land to those uses. Changes in land use have broad implications for the socio-economic and environmental services provided by the region's land base. Moreover, land use change can have feedback effects into climate change by modifying the amount of greenhouse gases (particularly CO,) that are emitted to the atmosphere and the amount of carbon that is sequestered in terrestrial sinks (IPCC, 2000).

This section begins with information on current land use trends in the Southeastern U.S. This is followed by a brief description of the approach used to model land use change within the region. The land use model is used to project regional land area in forests to the year 2040 under a no-climate-change scenario and under several combinations of the agriculture and forest climate change scenarios presented above. The land use results arc presented and discussed in the context of factors other than climate change affecting land use. Key model sensitivities and limitations that can affect the nature and relative magnitude of the modeled impacts are also discussed. With these caveats in mind, some general implications of the land use results conclude the paper.

2 LAND USE TRENDS IN THE SOUTHEASTERN U.S.

The Natural Resources Inventory (NRI) has intensively surveyed land use in the United States since 1982. NRI data (Natural Resource Conservation Service, 1999) are used to construct Figure 1, which shows land use trends on non-federal land in the Southeast by the major categories from 1982 through the most recent survey year 1997. Forest covers almost three-fifths of the region's land area and agriculture (cropland and pasture combined) accounts for almost one-quarter. The remainder of the land includes all urban-developed uses (about 10%) land as well as rural lands not categorized above (e.g., farm structures, marshlands). Lands under the Federal Conservation Reserve Program (CRP) are included under "other".

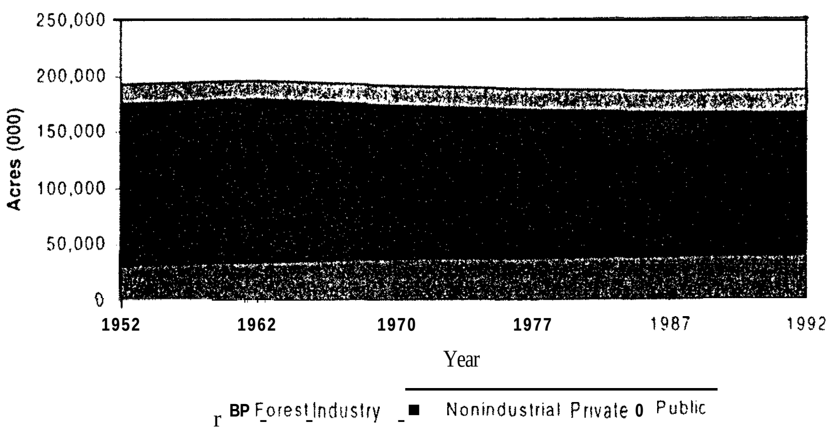
From 1982-1997 the region experienced a rather substantial decline in agricultural land and a dramatic increase in developed land. Cropland losses amounted to 11.6 million acres (21%), pasture/range declined by 3.3 million acres (8 percent). Meanwhile, urban-developed land area rose by 10.6 million acres, a 57% increase from 1982 levels. Over the same period, aggregate forest area change was fairly small -- about a 1.7 million acre decline (1.1 %), but this does not imply that the forest base was static. Forestland was also converted to developed uses, but movement of land



[a] States included: AL. AR, FL, GA. LA, MS. NC. SC, TN, VA. Source: NRI, 1999

Figure 1 Major uses of non-federal land in the 10 southern states: 1982-1997[a]

from agriculture to forest nearly offset those losses. The balance of land that left the categories of cropland, pasture-range, and forest but is not accounted for in urban-developed uses is primarily in the CRP category (about 3.2 million acres). Note that much of the region's CRP land is in



Sources: Alig et al., 1990: Powell et al., 1994

Figure 2 Timberland area trends for the Southeast Region: 1952-1992 trees, but is nonetheless classified separately by NRI. Therefore, land with tree cover may have actually increased between 1982-1997.

Figure 2 provides a look at forestland trends further back in time. Total forest area rose in the 1950s, then declined from the 1960s through the mid-1980s and stayed relatively stable through the early 1990s. The trends in forestland by ownership type indicate a couple of key points. First, the region's forest base is overwhelmingly in private hands (over 90%), predominately non-industrial private forest (NIPF). However, NIPF has declined as a share of ownership, with slight gains by forest industry and public forest lands. More detail on NIPF ownership characteristics is found in Moulton and Birch (1995).

3 ECONOMIC MODELING OF LAND USE CHANGE

Because most land in the Southeast U.S is under private ownership, its use is largely determined in a competitive land market setting. As a result, a properly structured and estimated econometric model can be used to simulate land allocation within the region. Econometric studies of the allocation of private land in the Southern U.S. includes studies by White and Fleming (1980); Alig (1986); Alig, White and Murray (1988); Hardie and Parks (1997); and Hardie, Parks, Gottlieb and Wear (HPGW, 2000). The last of these studies provides the empirical foundation for the land allocation model in this assessment. Model details, including mathematical derivation of the methods for simulating climate change impacts are provided by the lead author upon request.

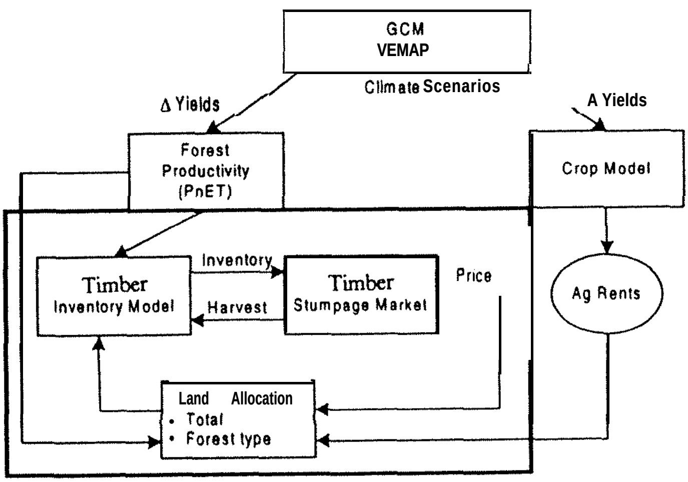


Figure 3 Model Overview

Figure 3 provides an overview of the approach we take to model climate and land use interactions. Climate affects the physical growth processes that determine agriculture and forestry economic returns (land rents). Changes in economic returns affect the way land is allocated on the margin. For instance, if climate changes the relative returns to forest and agriculture, then it will cause some land to shift from the relatively less profitable to the relatively more profitable use. This occurs regardless of whether the absolute changes in productivity are positive or negative. Changes in land use alter the supply conditions of the respective commodities. Movement of land from agriculture to forestry, for instance, would expand the (long-run) supply of timber and other forest commodities, but would contract the supply of agricultural commodities. Depending on the characteristics of the affected commodity markets, this may change the relative prices of the commodities, which further alters the relative returns to the uses and the incentive for marginal land use changes. This process continues until an equilibrium is reached between the land and commodity markets.

Many variables determining land use (population, income, housing values) are largely determined by forces external to the processes modeled within the integrated modeling system and are thereby treated as exogenous variables to the system. Data projections for those demographic variables are obtained from NPA (1999). Other determining variables (timber prices, agricultural income) are endogenously determined within the system. Therefore, our objective is to link timber and agricultural markets to the land market through the latter endogenous variables. Thus, the timber price and agricultural income effects induced by the climate scenarios, along with the exogenous demographic data projections, are fed into the land use model to simulate the resulting changes in land use. The land allocation solution is then fed back into the timber market model, thereby affecting long-run supply conditions and prices there, which are then fed back into the land model on a recursive basis. Similar feedbacks on the agricultural side are not included because regional agricultural commodity markets are not modeled in this assessment. Potential limitations of this exclusion are discussed below.

How sensitive are changes in land use to commodity market returns? The HPGW estimates land use elasticities for forestland in the range of +0.35. This indicates that a 10 percent rise in timber prices would generate a roughly 3.5 percent increase in timberland, holding all other variables constant. This elasticity is in the same range as those found in the other studies of Southern U.S. land use referenced above and is of similar magnitude to that found by Parks and Murray (1994) for private land in the Pacific Northwest U.S.

Climate change can also affect the incentives for intensive forest management. In the Southeast U.S., forest owners can either expend resources to establish and maintain plantations, generally of pine, or allow forests to evolve largely through natural processes. The former approach causes a forest stand to reach its economic optimum at an earlier age, but is more costly. Therefore, plantations are more economic when prices are high and the associated productivity gains are large. To the extent that climate change affects timber prices and plantation growth rates, it can change the incentives to establish plantations on forested land. We model the effects of timber price and productivity changes on the allocation of forested lands between planted pine and other types.

4 LAND USE SIMULATIONS

Land use simulations are performed for various scenarios in the timber market analysis discussed in Abt et al. (2001) and the agricultural analysis of Hatch et al. (2000). The model is capable of simulating all three major land uses (forest, agriculture, and urban/other) simultaneously; however, the forest area projections are the focus of our discussion here. Figure 4 features our model simulations of forest area outcomes under the no climate change baseline and under the base Hadley climate change scenario. The baseline (no climate change) model simulation: (1) captures feedback between the timber and land markets; (2) incorporates demographic variable projections; and (3) holds agricultural revenues and costs constant at base year values.

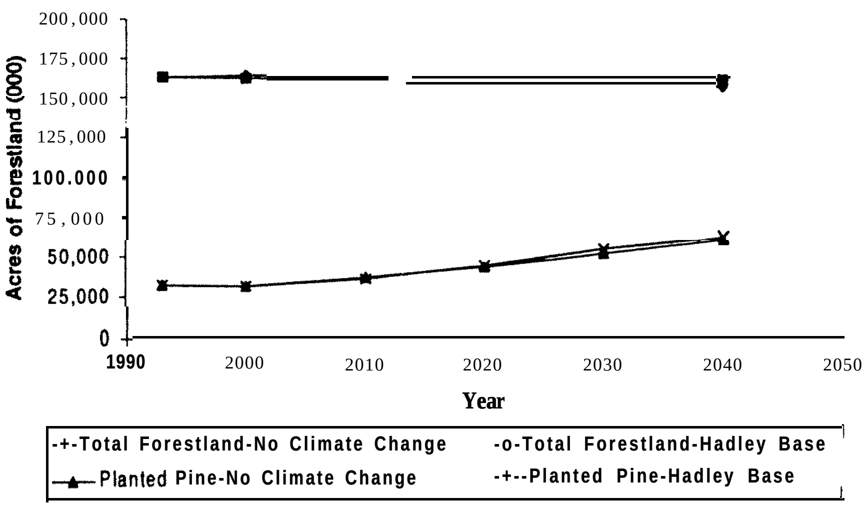


Figure 4 Forestland simulations: Hadley base vs. No climate change

Under the without climate change baseline, the total area of forest is projected to remain fairly constant over the period 1993-2040. Slight gains in forest are projected in the first two decades as forest incentives (rising timber prices) just offset the demographic factors inducing conversion to developed use. Thus forest losses to developed uses continue to be essentially replaced by forest gains from agriculture. Beyond 2010, a net decline in forestland is projected as the rising timber inventories cause timber prices to flatten, thereby reducing forestation incentives (see simulations in Abt et al., 2001). Meanwhile, population and income are still projected to increase and place pressure on forest conversion.

Model simulations under the Hadley 2 CMSUL (or “Hadley”) climate model base scenario project forestland to fall below the baseline for most of the first two decades, as the (softwood) productivity decline reduces the marginal profitability of forest as a land use. However, the rise in prices occasioned by climate-induced fall in timber inventory begins to dominate the forest productivity losses in the middle decades of the projection period. Moreover, during the middle decades, the softwood productivity losses start to turn into gains in the more northern parts of the region. Together this leads to net gains in forest area between 2010 and 2030 under the Hadley base scenario. Between 2030 and 2040, as timber prices start to come back to baseline levels, net forest area begins to decline. It is noteworthy that total forest area in 2040 evolves to virtually the same level under the Hadley and baseline scenarios.

Also included in Figure 4 are simulated projections of pine plantation acreage under the no climate change baseline and the Hadley base scenario. The first thing to note is that planted pine acres are projected to roughly double over the projection period under both scenarios. This continues the current trend of the region’s natural pine and mixed hardwood forests being converted steadily to plantations and is driven in part by rising softwood timber prices. At first, planted acreage under the Hadley scenario is slightly lower than baseline, but beyond 2020, the continued rise in prices, coupled with climate-induced improvements in site productivity cause the Hadley scenario planted acres to modestly exceed baseline levels.

Figure 5 shows the in&a-regional distribution of projected forest area change, 1993-2040, under the baseline scenario with no climate change. The NPA (1999) data provide county-level projections of population, income, and other demographic variables to 2040. Moreover, we assume that agricultural incomes remain constant throughout the projection period, which is consistent with regional trends of the last 3 decades. The simulation model projects relatively large forestland losses in the rapidly urbanizing areas of northern Virginia, central North Carolina (Raleigh-Durham to Charlotte), north-central Georgia (Atlanta metro area), and southern Florida. However, in the absence of climate change, relatively large transfers from agriculture to forest arc projected in regions spanning from southern Georgia through northern Mississippi and in various other spots throughout the region. Figure 6 compares land allocation in 2040 with and without simulated climate change. The simulation suggests that climate change under the Hadlcy scenario would lead to relatively more forestland in the northern reaches of the region than would be the case without climate change, with more neutral and somewhat negative forestland effects in the more southern sections.

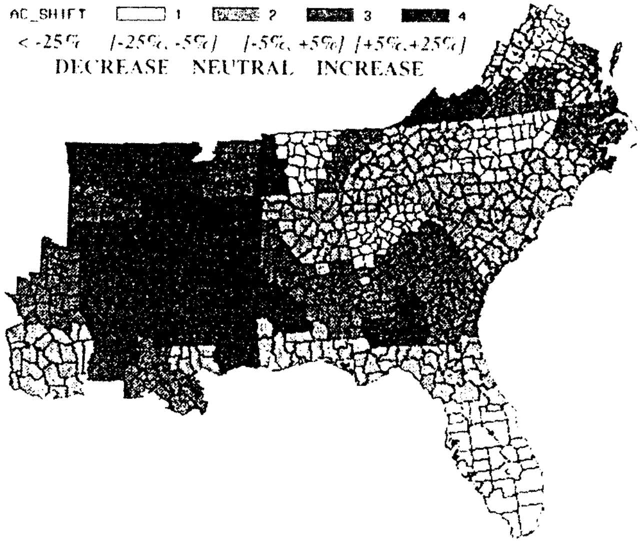


Figure 5 Timbcrland acreage shift, 1993-2040: No climate change baseline

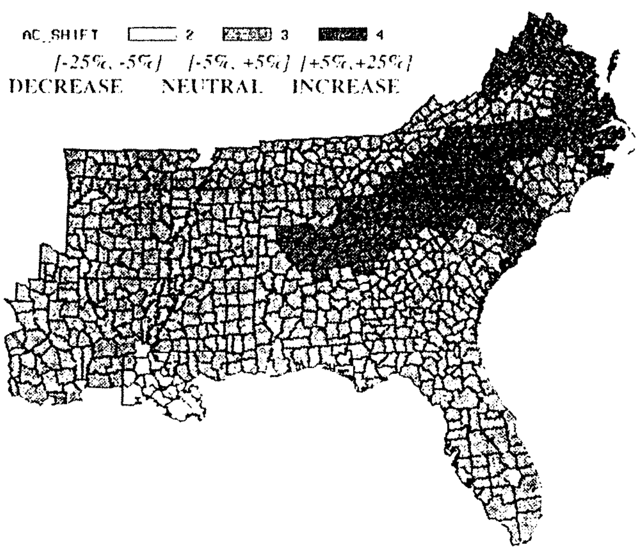


Figure 6 Timbcrland acreage difference, 2040: Hadlcy base case relative to no climate change baseline

Sensitivity to Variations in Timber Market Demand Scenarios

As discussed in the Abt et al. paper, our base assumption is that demand for Southeastern timber is fairly inelastic (elasticity value of -0.5) and that timber demand will grow roughly at the rate of the population. The model simulations include variations on the demand elasticity assumption to capture more elastic demand for Southeastern U.S. timber due to substitution with timber from other regions (that may be more or less favorably affected by climate impacts on forest productivity) and with materials other than timber.

The sensitivity of model simulations of the Hadley base scenario to timber demand assumptions is illustrated in Figure 7. The top line (indicated "inelastic demand") corresponds to the Hadley base scenario in the previous figure. Recall that a decline in demand growth or demand

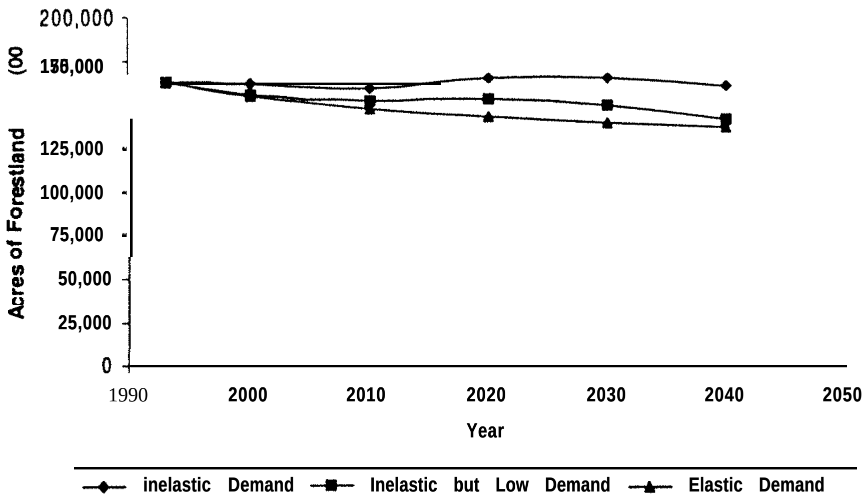
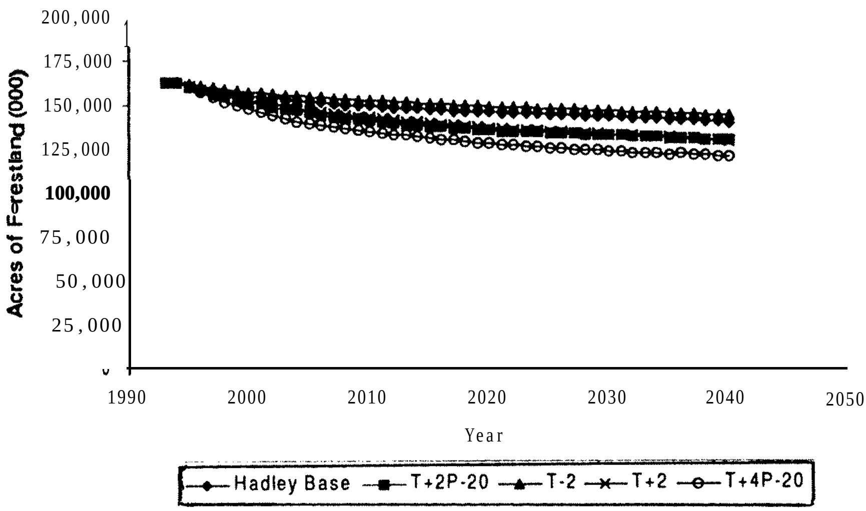


Figure 7 Sensitivity of forestland simulations to regional demand assumptions: Hadley base scenario

elasticity substantially lowers the rate of price increase for the region; the "elastic demand" scenario simulates an essentially fixed regional timber price throughout the region (regional demand elasticity = -50.0). Without a corresponding rise in timber prices, the combined effect of declining softwood productivity and demographic pressures would generate a fairly steady decline in regional forestland by 2040 (over 20 million acres).

Sensitivity to Variations in Climate Scenarios

Variations in the forestland simulations in response to different climate scenarios is illustrated in Figure 8. Because agricultural net income estimates from Hatch et al. (2000) are available only for the Hadley base runs, these simulations do not account for any climate-induced change in agricultural land returns. Therefore, they should not be interpreted as exact projections of forest areas under the different climate scenarios; rather, they



[a] **Elastic demand assumption, agricultural income effects not modeled**

Figure 8 Sensitivity of forestland simulations to different climate scenarios*

collectively provide evidence of model sensitivity to this form of variation. The climate scenario indicating a 2-degree warming above the Hadley base (T+2), indicates a moderate exacerbation of simulated forest area decline (10 million acres by 2040) due to the further diminished forest productivity. The additional effect of a 20% decline in precipitation (T+2P-20, relative to T+2) is undetectable on forest areas. The combined effect of Hadley + 4-degrees and a 20% decline in precipitation leads to a more substantial simulated decline in forestland (up to an additional 20 million acres).

5 SUMMARY, LIMITATIONS, AND AREAS FOR FUTURE RESEARCH

Summary of Findings

Although forests and agriculture dominate the Southeastern U.S. landscape, the effect of a changing climate on the relative productivity of these activities is just one of many factors that will determine how the region’s land will be used in the 21”’ century. Urban and other developed uses, while currently a relatively small part of the regional land base, have expanded dramatically in the last two decades and are likely to continue to do so in the future. In recent years, much of the forest area lost to development in the region was about equally offset by gains from forest establishment on previously agricultural land due to the decline in agricultural returns. This has tended to stabilize net forest area trends while exacerbating losses in agricultural land.

But relative changes in forest and agricultural returns potentially brought on by climate change could change the pattern of stable forest areas in the future if, as some scenarios suggest, agriculture can adapt to climate change in some parts of the region better than forests can. When we analyze the potential implications of climate change on land reallocation under the Hadley base scenario, our model simulations suggest relatively little change in the way that land is allocated between forests and other uses between now and 2040. However, variations from the Hadley base (e.g., Hadley + 2 or 4 degrees) could have more dramatic effects on land allocation. These more dramatic results should be evaluated with caution, however, as we have more limited information on the effects of climate change on economic returns to agriculture than on returns to forestry.

Model Limitations and Areas for Future Research

As just indicated, one limitation of our modeling approach is the imbalance of information on climate-related economic effects in the forest and agricultural sector. Moreover, while the land model explicitly integrates with the SRTS timber market model, no link to agricultural commodity markets is forged. Therefore, while reallocation of land between forests and agriculture does affect the simulated timber prices, any effect on agricultural prices remain undetected. This model shortcoming may not be too problematic if agricultural prices for the southeastern U.S. are largely determined by national and global commodity markets. However, if the land transfers are substantial enough, some effect on commodity prices seems likely. Thus further integration of the forest, agricultural, and land sectors may be warranted. These inter-sectoral linkages have been modeled at the national level by Adams et al. (1996).

Another limitation to consider is the narrow focus of our analysis on one region. While this has allowed for a more detailed examination of intra-regional phenomena, it ignores the effect that climate impacts elsewhere might have on the region. Nowhere is this more relevant than in commodity production and land use. As described herein, differences across region's in forest and agricultural impacts could have a substantial effect on the southeastern U.S.'s comparative advantage in the relevant commodity markets. This, in turn could have a more important impact on how land is allocated than on the relative impacts on forests and agriculture within the region that are modeled here. An examination of these interregional issues can draw from the work of others (Perez-Garcia et al., 1997; Sohngen and Mendelsohn, 1998) who have examined this at the national and global market levels.

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